Design of an Elliptical hybrid cladding Borosilicate PCF for Flattened Dispersion and Confinement Loss

Kriti Parashar, Himanshu Joshi, Ramesh Bharti, Khushbu Sharma

Abstract— **The photonic crystal fibres (PCF) are more better than conventional optical fiber. In this paper we proposed a new design of photonic crystal fiber using borosilicate material. Triangular lattice is used with linear and elliptical waveguide in cladding. The PCF are very useful for optical transmission. For better transmission, ultra flattened dispersion or near to zero dispersion is desirable. Finite Difference Time Domain (FDTD) method and transparent boundary condition (TBC) is used to evaluate the dispersion property in a high-index core PCF. Through reproduction and optimizing the PCF, we find that the projected photonic crystal fibres give flattened dispersion in wavelength range of 0.5µm to 2.0 µm. This method produced best result at third attenuation coordinate (1.55µm) over 1.4 µm to 1.8 µm wavelength range and found the dispersion and ultra flattened that has better performance than conventional photonic crystal. PCF can be used as a dispersion compensating fiber in optical window with high potential.**

Index Terms—**Chromatic dispersion, photonic crystal, square lattice, Effective Refractive Index (neff), Finite Difference Time Domain (FDTD) method, Transparent Boundary Condition (TBC)**

I. INTRODUCTION

Optical fiber is frequently used in wavelength division multiplexing (WDM) network for optical data transmission. In WDM communication systems, it is fundamental to maintain a identical response in the different wavelength channels, which requires that the transmission line proceed the ideal state of ultra flattened dispersion and ultra-low loss [1] .But stretchy dispersion or victims in optical fiber have been become a major problem in high bit rate wavelength division multiplexing optical communication systems. The dispersion is a incident that causes to broaden optical pulses, when they extend in the optical fibers [2]. So when a pulse come to receiver, it is not possible to distinguish whether it high or low. The inter symbol interference (ISI) can occur between the bits in communication channel, by transmission process & communication process superiority [3] [4]. Because of this, zero and flat dispersion slope with low losses are needed in high speed optical communication. Thus, a new technology of manufacturing photonic crystals has led to a new generation of optical fibers, namely Photonic Crystal Fibers [5]. The PCF has some features such as convenient dispersion, very low confinement loss and elastic design. The photonic crystal fibers (PCFs) are also called microstructures fibers or holey fibers. The photonic crystal fiber structure is formed by a core and a cladding [6]. The cladding is two dimensional photonic crystal types consisting of air holes that run along the fiber length show exceptional properties [7].

Light guidance in PCFs is depending on the core and cladding photonic crystal materials. The refractive index difference between the core and cladding is always positive in index-guiding PCF [8]. It can be possible by choosing a core material with a higher refractive index than the cladding refractive index. The photonic crystal fiber is also known as solid core photonic crystal fiber. These fibers guide light through a form of total internal reflection (TIR).The refractive index of the cladding is higher than refractive index of the core in the fibers with air core. However, in fibers with air core, TIR is not possible. So light guidance in these fibers attained by coherent Bragg scattering, where light at wavelengths within well-defined stop bands is forbidden from propagating in the photonic crystal cladding and is confined to a central defect[7]-[8] .Only some wavelength bands are confined and guided down the fiber. Each band corresponds to the presence of a full two-dimensional PBG in the photonic crystal cladding. For this cause, these fibers are called photonic band gap fibers (PBGFs) or hollow core fibers in which light is guided in a low-index core by the PBG effect.

Falling dispersion & confinement loss are main aim to designing PCF's. To designing PCF's, multiple parameters can change such as diameter & shape of the holes, the number of air hole ring and the spacing between these holes. Many designs of PCF's have been projected for the nearly zero ultra-flattened chromatic dispersion and low confinement loss.

II. THEORY OF DISPERSION

The dispersion (D) is proportional to the second derivative of the effective refractive index (ηeff) with respect to the wavelength (λ) obtained as:

$$D = -\left(\frac{\lambda}{c}\right)\frac{d^2}{d\lambda^2}\left[Re\left(\eta_{eff}\right)\right]$$

Where Re [ηeff] is the real part of the effective refractive index, λ is wavelength, and c is the velocity of light in space. The total dispersion is calculated as the sum of the waveguide dispersion and the material dispersion obtained as:

$$D(\lambda) = DM + DW$$

Where DM is the material dispersion and DW is the waveguide dispersion. The value of material dispersion is depending on value of effective refractive index of the material. The effective refractive index is directly obtained

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from the three-term Sellmeier formula [6].

$$\eta^2=1+(A_1\lambda^2)/(\lambda^2-\lambda_1)+(A_2\lambda^2)/(\lambda^2-\lambda_2)+(A_3\lambda^2)/(\lambda^2-\lambda_3)$$

Where λ is operating wavelength in µm and A_1, λ_1, A_2, λ_2, A_3, λ_3 are the sellemeier constants which changes with the material properties. The sellemeier constants are different for different material. For Borosilicate Crown Glass sellemeier constants are:

A_1=1.03961212 λ_1= 0.774642 µm

A_2=0.231792344 λ_2=0.141484677 µm

A_3=1.01046945 λ_3=10.1764753 µm

Material Dispersion refers to the wavelength dependence of the refractive index of the material caused by the interaction between the optical ions in the material. Refractive index of the air hole is one. Material dispersion remains unchanged for different lattice structure of designed PCFs.

Confinement Loss: An additional imperative loss is confinement or leakage loss [1-5] [9-11] originates from the finite width of the cladding structure. By selecting the parameters *d* and Λ properly in PCFs we can formulate confinement loss minor. Low confinement loss may be achieved for small core PCFs by coming up with the fibers with a minimum of 6 rings of air holes for a closely packed structure. Raising the amount of air hole rings ends up in a supplementary reduced confinement loss [1][3][4-5] [9-10]

$$\text{Confinement Loss (dB/m)} = 8.686\ \text{Im}[k_0 * \eta_{eff}]$$

Where $k_0=\frac{2\pi}{\lambda}$, λ is wavelength of light and η_{eff} is the effective refractive index of the proposed.

III. DESIGN PARAMETER AND SIMULATION RESULT

The new design of the photonic crystal fiber is shown in Figure 1 to Figure 3. In this design triangular lattice is used of borosilicate crown glass with1.5168 refractive index and the refractive index of the air hole is 1.0. The cladding in this PCF is poised by linear waveguide and elliptical waveguide with circular and elliptical air holes. This PCF structure is made up of six layer hexagonal lattice structure. The spacing between the centers of adjacent holes, Λ is 2µm.

a. Configuration 1:

The PCF structure is made up of six layer hexagonal lattice structure with inner two layer is circular holes which d=0.6 µm, third layer major axis 0.6 µm and minor axis 0.8 µm, forth layer is elliptical where a (major axis) =1.0 µm, b(minor axis)=0.8 µm and 5,6 layer is d=1.0 µm.

b. Configuration 2:

The PCF structure is made up of six layer hexagonal lattice structure with inner 2 layer is circular holes which d=0.6 µm, third layer change into elliptical holes which d of major axis=0.6 µm and minor axis =0.8 µm, forth layer major axis is d=0.8 µm and minor axis is d=1.0 µm, fifth and sixth layer d=1.0 µm.

c. Configuration 3(proposed model):

The PCF structure is made up of six layer hexagonal lattice structure with inner 2 layer is circular holes which d=0.6 µm, third layer major axis=0.8 µm and minor axis =0.6 µm, forth layer major axis is d=1.2 µm and minor axis is d=0.8 µm, fifth layer major axis d=1.0 µm and minor axis 0.8 µm, sixth layer d=1.0 µm.

Note: According to our design configuration the best one is configuration 3.

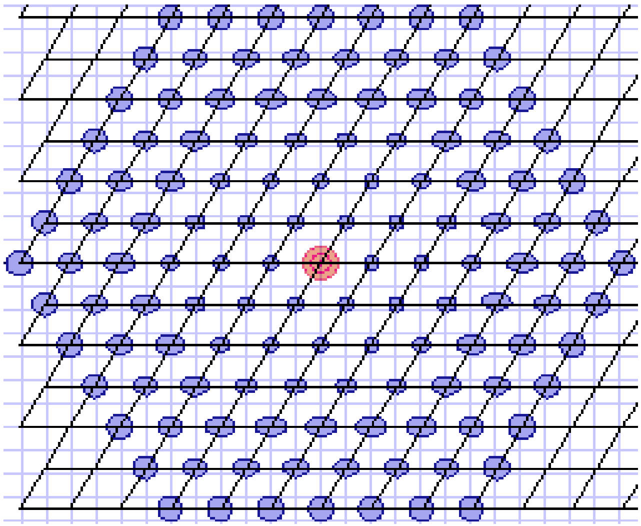

Fig. 1 Air-hole distribution of the Proposed Hybrid Structure for Design-3

IV. RESULT

In the proposed work there is a comparison between all the three designs is based on Total dispersion (chromatic dispersion) as shown in Figure 2 and Confinement loss as shown in Figure 3. The total dispersion or chromatic dispersion is the sum of waveguide dispersion and material

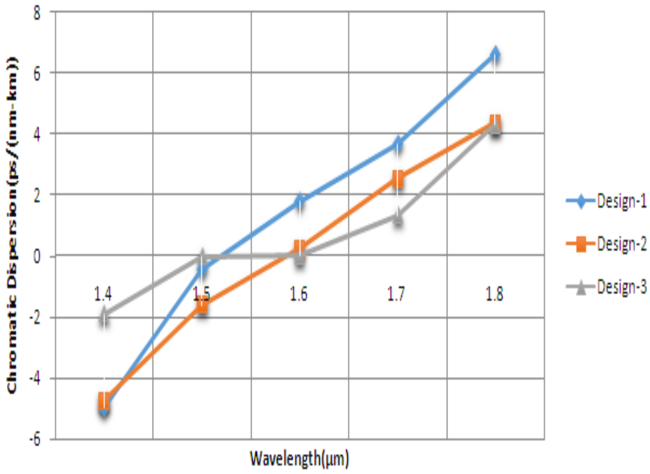

Fig. 2 Comparison of Chromatic dispersion for Design-1 to Design-3

dispersion. For above all the Design-1 to Design-3, we can conclude that design-3 gives more flatten dispersion in range 1.4 µm to 1.8 µm wavelength as compare to other two designs. So that Design-3 is proposed design for the zero order dispersion as shown in Fig 1.

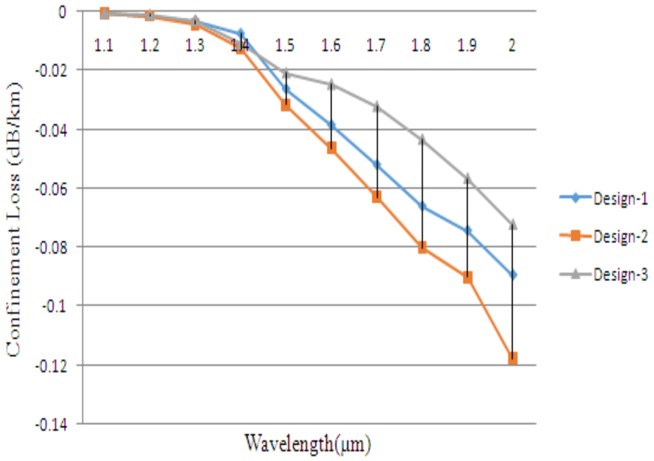

Fig. 3 Comparison of Confinement Loss for Design-1 to Design-3

Table 1 Comparison between Proposed Design-3 with Reference Paper-1

Design	Flatten dispersion in wavelength 1.4 to 1.8 μm	Confinement Loss in wavelength 1.4 to 1.8 μm
Ref-1	-4.50 to +5.0 (ps/(nm-km)))	NA
Proposed Design-3	-1.89 to 4.3 (ps/(nm-km)))	-0.01091 to -0.04334 dB/km

For above the Design-3 and reference paper-1, we can conclude that Design-3 gives flattened dispersion, zero order dispersion and low confinement loss in the range 1.4 μm to 1.8 μm as compare to design of reference paper-1 so that design-3 is proposed design.

V. CONCLUSION

According to our configurations the best one is configuration 3 that structure simulations results get zero dispersion at 1.55μm and ultra flattened and low confinement over 1.4μm to 1.8μm wavelength range that has better performance than conventional photonic crystal fiber. We can use Borosilicate crown glass as a core material on the place of silica glass because Borosilicate crown glass has good properties (like cheaper, good transmission, easy availability) and BK7 is very good transmission down to 400 nm.

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